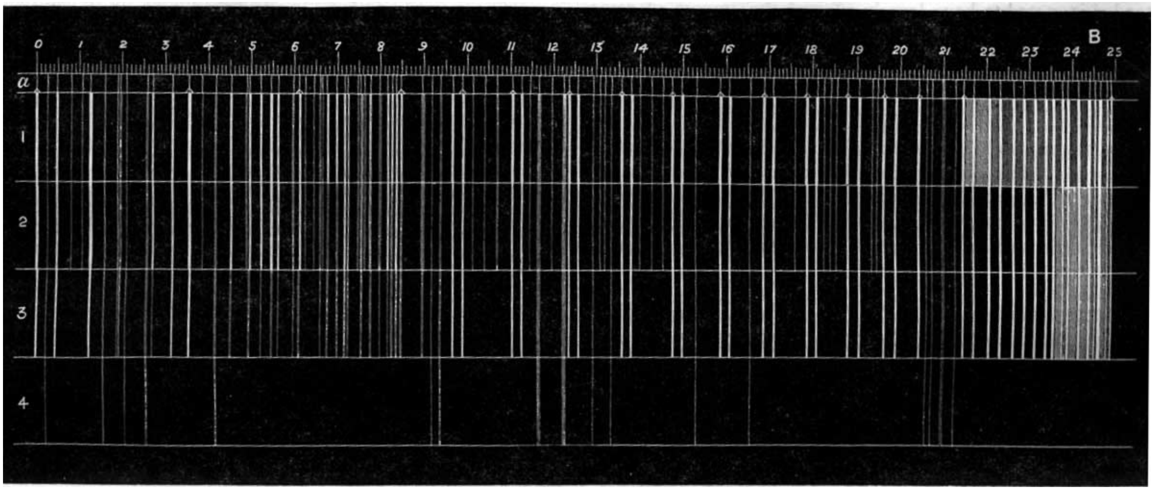
CONSTITUTION AND ORIGIN OF THE GROUP B OF THE SOLAR SPECTRUM[1]

WHEN a single prism spectroscope is directed towards the sun at the moment when it is in the neighbourhood of the zenith, we perceive near C, at about a fourth of the distance separating it from the extreme red, a strong black line, which Frauenhofer has named B. Under a more powerful instrument of five or six prisms this line becomes a very black broad band, separated from the region of C by what may be described as almost an empty space, the lines which do exist in it being few and faint. On the other side this band is followed by well-marked lines, which appear to be very regularly spaced, and the first of which show some indications of being double. Father Secchi had vainly attempted to resolve the band B ; on this subject he writes :—

"Certain bands which in ordinary instruments seem to be stumped consist in reality of numerous perfectly distinct lines, as is seen in a spectroscope possessing great dispersive power ; but some of them are really massed towards the edge, and there it is impossible to separate them, however powerful the instrument employed. We may cite as an example the lines of the group B" (*Le Soleil*, vol. i. ed. 1875, p. 235).

The statement of the learned physicist shows that, at the time he wrote the above, spectroscopic apparatus had not been brought to very great perfection or power. In point of fact the dispersion of eight or ten prisms suffices to show that the band B is really formed of a large number of distinct lines. With my highly-dispersive instrument it becomes resolved in a truly marvellous manner. The seventeen lines composing it are distinguished with the greatest clearness, and may be very exactly measured. Those following it on the red side are all broadly doubled, presenting in their regularity a very remarkable appearance.

In 1878 Messrs. Piazzi-Smyth and Langley succeeded for the first time and almost simultaneously in resolving this group. Piazzi-Smyth, working with prisms, obtained only an incomplete resolution, whereas, by means of Rutherford's excellent appliances Langley not only separated all the lines, but also determined their wave-lengths. Being unaware of the work of these physicists, I fancied I had been the first to obtain these results in 1879, when making the first essays with my highly-dispersive apparatus. The sulphide of carbon compound prisms, which M. Laurent had just made, were merely mounted on a drawing-board, were badly regulated, badly sheltered from variations of temperature, and could not yield the results that I now obtain. The drawing which on that occasion I published in the *Comptes Rendus* is incomplete and inaccurate. That which accompanies this article has been made with the greatest care and to a scale on which the errors of position can scarcely exceed 1/10 mm. It is more complete than any I have yet seen.



Solar Spectrum—Region B, by M. L. Thollon.

a. Position of the lines.
1. Mean aspect of region B when the sun is 80° from the zenith.
2. ,, ,, ,, 60° ,, moist weather.
3. ,, ,, ,, 60° ,, dry ,,
4. Non-telluric lines. Spectrum of region B as it would appear if observed outside the atmosphere.

The explanations given at the foot of my design enable us to recognise at a glance : (1) the metallic lines, (2) the telluric lines produced by the variable element of the atmosphere (beyond all doubt aqueous vapour) ; (3) the telluric lines proceeding from the constant elements (oxygen, nitrogen, carbonic acid). The group is thus seen to consist of a pencil of seventeen rays, constituting properly speaking Frauenhofer's B-band ; of a system of twelve couples with intervals increasing regularly from right to left, whereas the distance of the constituents diminishes with equal regularity in the opposite direction ; lastly, of a somewhat important group belonging to the vapour of water, the whole interspersed with a few weak metallic lines.

When we survey the solar spectrum given by my apparatus, beginning with the violet, and when we behold the thousands of lines composing it distributed in all the regions without any apparent kind of order, on arriving at the group B we feel, as Mr. Langley remarks, the same impression as does a traveller lost in a virgin forest when he suddenly finds himself in the presence of a perfectly straight avenue of trees planted with mathematical regularity. It should be added that A at the extreme red, and α comprised between C and D are identically constituted. If they attract less attention it is because A is nearly at the limit of the field of vision, while the regularity of α is disguised by a large number of lines foreign to its origin. Beyond these three cases chance alone seems to have presided over the distribution of lines throughout the whole spectrum.

But the interest attaching to these groups is due not only to their remarkable appearance, but also and especially to the question of their origin. In what regions are produced the absorptions which give them birth? In the solar atmosphere, in the terrestrial atmosphere, or in some medium comprised between the sun and the earth? Do these absorptions proceed from a common element, and if so what is its nature? The most contradictory answers have been given to these various questions, which have already long since been asked.

To speak only of B, after his memorable experience of La Villette in 1866, M. Janssen asserted that this group was at least to a great extent due to aqueous vapour. The little sketch published by him in the *Annales de Chimie et de Physique* (4th series, vol. xxiv. p. 217) in fact shows, facing B, bands of absorption due to the vapour of water, and corresponding exactly to the spectral bands yielded by the setting sun in this region. On the other hand, Ångström, who had devoted much study to the question, tells us that at the low temperature of 27° C.,

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[1] Paper by M. L. Thollon in *Bulletin Astronomique*, May 1884.

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when the other telluric lines had almost entirely disappeared, he saw B perfectly distinct. At a like zenith distance from the sun this group seemed to him even blacker and more intense than usual. Hence his inference that it could not proceed from the vapour of water. This eminent physicist, a thoroughly convinced partisan of spectral unity for the simple gases, had ascertained that in the spectrum of atmospheric emission there was no trace of any ray or band corresponding to B. It followed for him that the air could not absorb radiations it was incapable of emitting. If therefore this group, variable like the other telluric rays, could be attributed neither to aqueous vapour, to nitrogen, nor to the oxygen of the air, from what element did it derive its origin? Ångström spoke of carbonic acid, but perhaps without believing in it. He seemed deeply interested in Tyndall's experiments on the absorbing power of gases by heat. We know that this skilful investigator had found that the coefficients of absorption of oxygen and nitrogen by no means corresponded with the coefficient of absorption of the air. The difference he attributed to some unknown element sufficiently rarefied to escape our analyses, and endowed with immense absorbing power. Ångström had probably this unknown element in his mind, but he remained uncertain to the last.

The great authority of the Swedish physicist could not fail to have its influence on the judgment of those approaching the question after him. Captain Abney, who has so greatly distinguished himself by his remarkable scientific labours, asserts in NATURE (October 12, 1882, p. 585) that the groups A and B cannot be regarded as telluric, but as proceeding from a medium lying between the sun and the earth. Piazzi Smyth, who had at first looked on B as telluric, seems to have finally adopted Captain Abney's views, and is disposed to think that B as well as A may after all be the product of some interplanetary medium. In his opinion the recent theories of Siemens seem to confirm his view of the case.

The attention that I have for several years paid to the portion of the solar spectrum stretching from A to *b* has naturally led me to deal with this subject. Here is the method by which I succeeded in separating and classifying the spectral lines. After certain preliminary measures taken with the greatest care to determine their exact position, each region of the spectrum is drawn on two maps. The first is intended to reproduce the appearance of this region when the sun is at 60° from the zenith, the second when at 80°. These distances have been chosen in such a way that in the latitude of Nice the observations may be continued throughout the year. When the weather seems favourable at the hour when the sun is in the desired position, the intensity of each line is marked on the map itself with all possible exactness, the hygrometric state of the air being indicated each time. The process is slow, delicate, and laborious, but the result is certain. After I have thus made eight or ten series of observations on each drawing, they are carefully examined, and the indications relative to any given line enable me confidently to decide:—(1) whether it is not metallic; (2) whether a telluric line belongs to a constant or to a variable atmospheric element. By this method I have been able to satisfy myself that A, B, and α are telluric groups due to the constant elements of the air. *At the same distance from the zenith they have always the same intensity.* I refer of course only to the main groups in each of them, and to the couples following them on the least refrangible side.

It remained to determine exactly to what atmospheric element the groups in question were to be attributed. M. Egoroff, Professor of Physics at the University of Warsaw, has recently succeeded in solving the problem. He had for several years ardently devoted himself to this inquiry, and in 1882 we jointly made a series of experiments on the subject in the Paris Observatory. A pencil of electric light directed from Mount Valérien on the Observatory, distant 10 km., gave us the spectrum of the telluric rays all but complete. There was no difficulty in distinguishing A, B, and α, which are so easily recognised. Capt. Abney has questioned the results obtained by us. Yet they are incontestable, and in any case the experiment can be easily repeated.

At last, after these preliminary studies, M. Egoroff, operating directly on oxygen closely compressed in a metallic tube, and traversed lengthwise by a pencil of strong light, has obtained the groups A and B. The thickness of the oxygen thus traversed was doubtless insufficient for the production of α. But however this be, it may now be confidently asserted that these three, which are of such remarkable appearance, and which so closely resemble each other, have their origin in the absorption due specially to atmospheric oxygen.

I need not dwell upon the importance of this result; but how is it to be reconciled with the observations of Messrs. Janssen, Ångström and Piazzi Smyth? To judge from the sketch contained in the *Annales*, and above referred to, M. Janssen must have seen in the spectrum of aqueous vapour bands corresponding to those of the solar spectrum in the region of B. One of them even coincides exactly with the chief member of the group. According to my own observations, to produce this effect the vapour of water would have to yield at this point a non-resolvable band, which would simply obscure the intervals between the lines, as is seen in the spectrum 1 of my drawing. This observation should then vary according to the hygrometric state of the air, and not, as it has always seemed to me, according to the height of the sun. Or else this band is not represented in the exact position it ought to occupy, and should be shifted more to the left, where in fact are found many lines of the vapour of water constituting an important group (see plate).

If, on the other hand, Ångström saw B more intense at a temperature of 27° C., it was doubtless owing to a simple effect of contrast. The other telluric lines being greatly weakened, those that retain their intensity must naturally appear blacker. Such an effect is frequently produced in the course of my observations, and against it I have to be constantly on my guard. And now how can we explain why the spectrum of absorption of the oxygen differs so much from its spectrum of emission? The lack of sufficient data renders all explanation impossible; but the certainty of the fact obliges us to conclude that *cold* has not the same properties as *incandescent* oxygen, and allows us to suspect that it may be the same with all gases.

In asserting that A and even B do not really vary in intensity when the sun approaches the horizon, such an eminent observer as Piazzi Smyth would have greatly surprised professional spectroscopists, were they not aware how difficult and delicate a matter is the management of an apparatus of highly dispersive power. Let but the luminous pencil be badly adjusted, the prisms less than faultlessly regulated, the slightest cloudiness settle on the surfaces, the images, especially in the extreme red, will at once appear as if drowned in the diffused light, which obscures the most evident effects and even disfigures their essential characters. Strange phenomena are often produced, the causes of which it seems impossible to discover, and which easily give rise to illusions. But when we work under favourable conditions with a well-designed and well-constructed apparatus, it becomes superabundantly evident that A and B vary considerably in intensity according to the height of the sun, and are certainly telluric.

During the total eclipse of 1882, both M. Trépied and myself fancied we observed on the edge of the lunar disk a notable strengthening of the rays of the B group. If Captain Abney's theory could have been confirmed, it would have certainly added great weight to our observations, and for my own part I should have felt highly satisfied at the result. Unfortunately, the atmosphere of oxygen which should now be attributed to the moon in order to produce the observed effects, seems scarcely reconcilable with the absence of refraction in the luminous rays striking the edge of our satellite. I greatly fear the results obtained in Egypt are one of those illusions, of which nearly all spectroscopists have been more or less the victims.

It would now be important to ascertain whether the nitrogen and carbonic acid of the air may not be represented by any line or any group in the solar spectrum. The study I am at present engaged in, according to the above described method, will not fail, I trust, to yield precise results on this important point. Hitherto, apart from the oxygen groups, I have discovered no line that may be confidently attributed to the constant elements of the atmosphere. Hence it is desirable to await the result of my researches before giving effect to the project adopted by M. Bischoffsheim to establish on Mont Gross metallic tubes of considerable length, in which the spectra of absorption of gases may be studied on a grand scale.

THE MIGRATIONS OF "SALMO SALAR" (L.) IN THE BALTIC

THE following statement gives further details supplementary to our recent article on this subject:—

Since the earliest times salmon have been caught in the Finnish rivers which had in their mouths or entrails hooks

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